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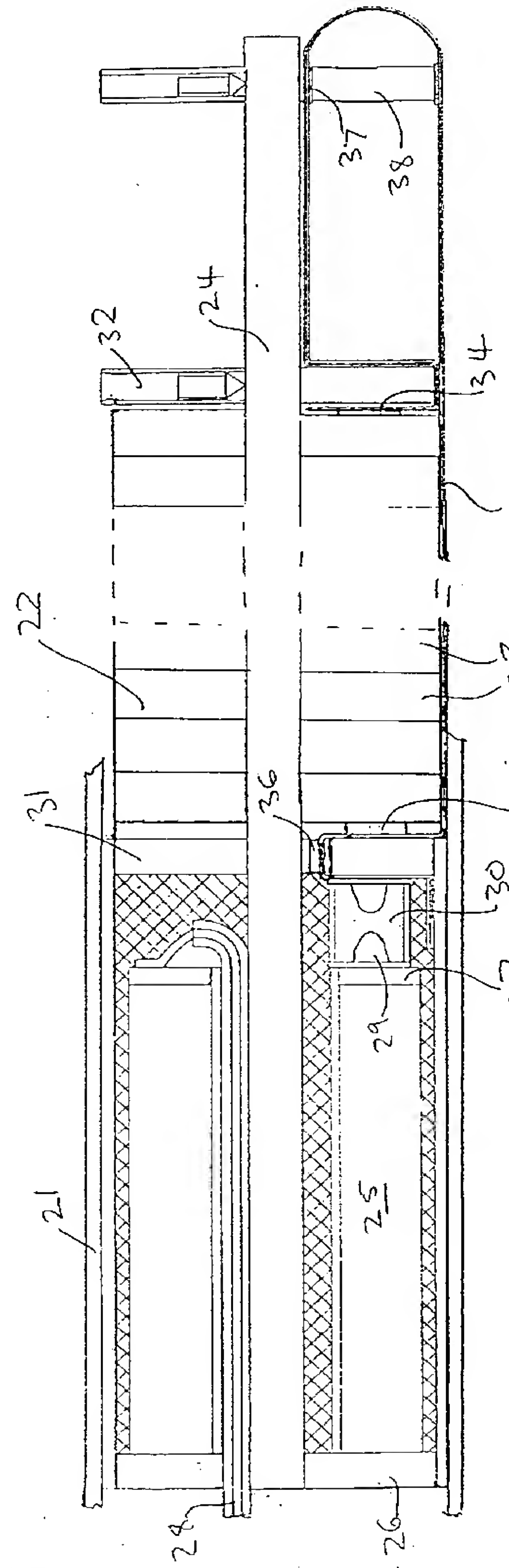
(54) **Explosive arrangements.**

(57) An explosive arrangement includes an explosive charge (22) which is detonated simultaneously from each end to produce opposing detonation fronts in the explosive. When the fronts meet, an outward force results which is used, for example, to cut through drills which have become jammed in a bore hole. The simultaneous detonations are produced by transmitting an electrical pulse along a stripline (35) via two EFI initiators (33 and 34) connected electrically in series by the stripline.

An end plate 32 is located adjacent to one end of the charge 22, being clamped in use on a central shaft 24. The end plate 32 is movable to allow variable lengths of charge to be used. Another plate 38 is also movable on the shaft 24 and by suitable adjustment enables one length of stripline to be used for different length charges.

Fig. 2

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This invention relates to explosive arrangements and more particularly to arrangements which are concerned with producing substantially simultaneous detonations of an explosive charge from two or more spaced apart initiation points such that detonation fronts travelling through the explosive material meet and produce an outward force.

In drilling operations, for example, in the oil industry, a drill is often used which consists of a hollow cylindrical shaft carrying a drill head or other tool. The shaft has a thick wall which must be robust enough to withstand the considerable strains placed upon it during operation.

Sometimes the drill head becomes jammed or obstructed in the bore hole. If it is not possible to remove the drill in order to steer around the obstruction, it is necessary to release the end of the drill from its shaft. This may be achieved using a explosive collar cutting assembly which is lowered down within the inside of the drill. The assembly has a thin cylindrical casing within which is packed an explosive material, typically HMX (High Melting Point Explosive). When the assembly is at the depth where it is believed the drill has become stuck, the explosive charge is detonated at both ends substantially simultaneously, producing detonation fronts within the explosive material which travel axially in opposite directions. Where the fronts meet, a radial outward force is produced which is sufficient to cut through the assembly casing and the wall of the drill shaft.

Figure 1 is a schematic longitudinal sectional view of a conventional collar cutting assembly as presently used.

The assembly comprises an outer casing 1 within which is located a hollow tube 2 which extends centrally along the whole length of the casing 1. The left hand end, as shown, is uppermost when the assembly is lowered into the drill shaft and includes a compartment 3 in which part of the detonation arrangement is housed. The remainder of the length of the casing is occupied by an explosive charge 4, typically of HMX, having a central aperture 6 through which the tube 2 passes. The length of the charge employed is chosen to control the magnitude of the explosive force created according to the requirements of a given situation. The charge 4 is bounded at each end by end plates 7 and 8 which are clamped into position on the tube 2.

The detonation arrangement for initiating the explosive charge 4 employs detonating cord. This consists of a plastic walled tube filled with explosive material. The detonating cord is initiated at one end and the explosion travels along it to deliver a mechanical shock to a main charge and hence detonate it. In the assembly shown in Figure 1, two detonating cords are used. One detonating cord 9 is folded within the compartment 3 and is used to detonate the charge 4 at its upper end. The other detonating cord 11 is located within the hollow tube 2 and extends to the lower end of the charge 4. The tube 2 must be cut to a suitable length depending on the length of charge chosen.

An initiator 14 is positioned at the upper end of the assembly, the ends 12 and 13 of the detonating cords 9 and 11 respectively being located adjacent to it. Typically, the initiator 14 is of the exploding bridge wire type in which an electrical pulse is passed through it to cause a wire to break. The resulting fragments impact on the ends 12 and 13 of the detonating cords to initiate them. A cable 15 forms a transmission line for the triggering electrical signal to the initiator 14.

The end 16 of the detonating cord 9 remote from the initiator 14 is clamped in position and abuts a booster pellet 17 placed adjacent the explosive charge 4. The detonating cord 11 located within the tube 2 is looped around the end of the tube and back on itself outside the tube 2 to a holder 18 where its end 19 is clamped against a booster pellet 20 placed adjacent the lower end of explosive charge 4.

To detonate the explosive charge, an electrical signal is transmitted along the cable 15 to the initiator 14 causing the explosive contained within the detonating cords 9 and 11 to ignite. The explosion fronts travel along the detonating cords 9 and 11 to the booster pellets 19 and 20 to initiate the main explosive charge 4 at two points. Providing the timing of the initiations at the upper and lower ends of the charge 4 is sufficiently close, the detonation fronts meet and produce an outward force which cuts through the drill shaft wall.

The detonating fronts travel through the detonating cords 9 and 11 at a speed of approximately 5000 metres per second. Therefore, the lengths of the detonating cords 9 and 11 are critical in order for initiation to occur substantially simultaneously at each end of the charge 4. The detonating cords 9 and 11 must be the same length to within tight tolerances to ensure that the detonating fronts meet in the explosive charge 4.

If the detonating cord 11 is longer than the other one, then the charge 4 will be initiated from the uppermost end first, and this may result in a downwards explosion which will not free the drill head. Alternatively, if the central detonating cord 11 is shorter than the folded detonating cord 9, the explosion of the main charge is initiated from the lowermost end first, and this can cause an explosive shock wave to travel upwardly through the drill, with the possibility of sensitive monitoring instruments on the surface being damaged.

Another difficulty encountered when using the assembly is in ensuring that the connections between the detonating cords and the initiator, and with the booster pellets, are sufficiently secure.

For safety reasons it is essential that radio silence be maintained during deployment the drill cut-

ting assembly as any electrical interference may be sufficient to unintentionally trigger the initiator.

The present invention arose from an attempt to produce an improved explosive arrangement suitable for use in drilling operations but it is envisaged that it may also be advantageously used in other fields.

According to the invention there is provided an explosive arrangement comprising: substantially elongate explosive charge means having a longitudinal axis; and initiator means comprising at least two initiators disposed substantially adjacent to the charge means and spaced apart from one another in a longitudinal direction, the initiators being electrically initated to detonate explosive material, the initiator means being arranged such that, when the initiators are initiated, detonation fronts are produced in the charge means sufficiently simultaneously so as to meet and thereby produce a force in a direction substantially transverse to the longitudinal axis.

By employing the invention, the detonating cord used in previous arrangements may be dispensed with as there is no need for an intermediary explosive between the initiator and the main explosive charge. The explosive path between the initiator and the main charge is very short in comparison with the length required in conventional arrangements using detonating cords to deliver a detonating force to the main charge. Thus the timing of the initiator firing is no longer governed by the velocity of detonation for the explosive of detonating cord but by the length of the time taken for an electrical signal to travel along electrical transmission lines to the initiators. The velocity of an electrical pulse along a transmission line is very much greater than that of an explosion travelling along a detonating cord. Therefore the tight tolerances previously imposed need not be observed with an arrangement in accordance with the invention. As it is not necessary to precisely measure the length of the electrical transmission line or lines involved in delivering the initiating pulse to the charge means, an operator may set up an assembly much more easily than is the case with a conventional assembly and hence the time for which drilling operations, for example, must be suspended is greatly reduced, giving significant cost benefits.

Another significant benefit which arises from using the invention is that as the explosive used in the detonating cord, which typically is PETN (Pentaerythritol-tetranitrate), need no longer be used, the assembly as a whole has improved temperature stability, enabling it to be used at depths of, say, 8 kilometres into the earth where temperatures may be in the region of 200° Celsius. The explosive charge means may typically include material such as HMX which is stable at these temperatures.

Another advantage which arises from eliminating the need to use detonating cord is that connections made between various components of the arrangement in accordance with the invention may be more secure, this sometimes being difficult to achieve with detonating cord. Also, it is not necessary to include a compartment for housing the folded detonating cord for connection to the upper end of the charge means and there is no concern about adjacent folded sections of detonating cord interfering with one another and causing a problem in the timing of the simultaneous detonations.

Although the invention may be particularly advantageously employed in explosive cutting arrangements it is believed to have uses in other fields also, for example, it may be used in seismic applications.

In some applications it may be necessary to have more than two detonation points. For example, it may be wished to create transverse forces at two spaced apart locations, in which case an initiator can be positioned at each end of the elongate charge means with a third initiator centrally located.

In a particularly advantageous embodiment of the invention, the initiators are of the exploding foil initiator type (EFI). An EFI initiator is fired by discharging a capacitor, or some other source of high current pulse, through it, causing a foil to vaporise and to produce a high velocity plastic disc or flyer which is directed onto an explosive to initiate detonation. The pulse may require a peak current amplitude in the range 4 to 10kA with a rise time in the range 20 to 100 nanoseconds. As these conditions are unlikely to be accidentally produced within the environment in which an arrangement in accordance with the invention is to be operated, such an arrangement is inherently safe. This has particular advantages in the drilling industry. At present, radio silence must be maintained whilst an explosive cutter is deployed and all activities giving rise to potentially interfering electrical signals must be shut down. By employing the invention, normal activities may be maintained where these do not directly interfere with the deployment of the explosive device and radio communication can be continuous, enabling personnel to be updated as to the progress of the operation to free a drill head.

In one preferred embodiment of the invention, the initiators are electrically connected in series so that the same electrical pulse travelling along a transmission line fires two initiators one after the other. Over a typical length of travel of one metre, there is a delay of the order of 3 to 10 nanoseconds between initiation of the first and second initiators. Where the initiators are arranged electrically in series, only one electrically conductive track is required, simplifying the arrangement. However, for some requirements, it may be preferable to have the initiators in parallel or independently fired.

Preferably, at least one of the initiators is connected to stripline along which an electrical firing signal is transmitted. Stripline is particularly convenient because of its low inherent inductance enabling the

fast current rise times necessary for use with EFI's to be achieved. It is also easily handled and good connections to it may be readily made.

In one embodiment of the invention, at least one of the initiators is arranged to be directly in contact with explosive of the charge means. However, in some circumstances, it may be desirable to include an intervening booster pellet to amplify the mechanical shock produced by the initiator to initiate the secondary explosive of the explosive charge means. In either case, one or both of the initiators may include a plate member, a piece which of breaks off upon triggering and is expelled with the vaporised foil, in the case of an EFI,to transmit the mechanical shock directly to the secondary explosive of the charge means or via a booster pellet.

Preferably, the electrical signal to one or both of the initiators is transmitted by a spark gap device, which conveniently is of the over voltage type. In such an arrangement, it may be preferred that one terminal of the spark gap device be directly adjacent, and in physical contact with, an electrical transmission line for transmitting the signal to the initiator or initiators. The other terminal of the spark gap device may be in contact with a terminal of a capacitor from which an initiating pulse is derived when the spark gap exceeds its breakdown voltage.

Preferably, the arrangement includes a housing in which the explosive charge means and the initiators are contained. Also, a capacitor may be included within the housing so as to ensure that the distance along which an electrical pulse is transmitted is minimized, hence reducing inductive losses. The capacitor may be charged by a line from the surface providing a high voltage supply. However, it may be preferable to include a transformer within the housing for the capacitor supply to permit use with a low voltage.

In a particularly advantageous embodiment of the invention, an end plate is included adjacent one end of the explosive charge means, the end plate being movable in a longitudinal direction. This allows the amount of explosive material of the charge means to be varied as desired. It is also preferable that a second movable plate be included, being located on the side of the end plate other than that adjacent the charge means. One of the initiators may be mounted on the end plate and connected by an electrical transmission line to pulse supply means, the electrical transmission line being taken around the second plate or through an aperture therein. Such an arrangement enables different lengths of explosive charge to be used without needing to cut the transmission line to a particular length. The explosive charge is loaded into the assembly and the movable end plate placed adjacent it. The second end plate is then moved in the opposite direction to take up any slack in the transmission line.

Some ways in which the invention may be performed are now described by way of example with reference to the accompanying drawings in which:

Figure 2 schematically illustrates part of an explosive arrangement in accordance with the invention;

Figures 3a and 3b are explanatory diagrams relating to the operation of the arrangement of Figure 2;

Figure 4 is a schematic external view of an assembly including the arrangement of Figure 2; and

Figure 5 schematically illustrates another arrangement in accordance with the invention.

With reference to Figure 2, a collar cutting assembly for deployment in bore holes to cut through drills includes a cylindrical outer casing 21, only part of which is shown, within which is housed a main explosive charge 22 of HMX. The charge 22 is in the form of apertured discs 23 located on a central shaft 24. The assembly typically has a diameter of about 5cm and a length of 1m.

The left hand end of the assembly, as shown, which is the uppermost end when in use, contains a cylindrical low inductance capacitor 25 having an earthed terminal 26 and an HT terminal 27 to which charging current is applied via a lead 28. The HT terminal 27 is in direct physical contact with a terminal 29 of an adjacent spark gap 30 of the over-voltage type.

The main charge 22 is bounded by two end plates 31 and 32 which are clamped to the shaft 24 and secure the charge 22 in place. An EFI initiator 33 and 34 is mounted on each end plate 31 and 32 respectively so that it is directly adjacent to an end surface of the charge 22. The two EFI's 33 and 34 are electrically connected in series by low inductance stripline 35. The stripline 35 extends from the spark gap device 30 via an aperture 36 in end plate 31 and to the first EFI 33 to which it is connected. The stripline 35 is positioned along the length of the charge 22 over its outer surface, with the high voltage side of the stripline being on the inside. An electrically insulating film covers the inner surface of the stripline 35. The stripline 35 passes through an aperture 37 in another plate 38 and is connected to the second EFI 34, being fixed to the end plate 32. The insulating film ensures that the adjacent parts of the stripline 35 do not form a short circuit.

When it is wished to deploy the assembly, the amount of charge required is estimated and an appropriate number of discs 23 placed in position to form the charge 22. The assembly is lowered into the central cavity of the drill shaft to the desired depth. The capacitor 25 is then charged via HT lead 28. The spark gap device 30 typically has a breakdown voltage of 3 to 4.5kV and when this exceeded, the capacitor discharges through the spark gap 30 to produce a pulse which is transmitted along the stripline

35, causing the initiators 33 and 34 to be triggered in turn. The value of the capacitor is chosen so as to be able to produce a current pulse with a peak amplitude of about 6kA and a pulse rise time of approximately 30 nanoseconds. Typically, there is a 3 and 10 nanoseconds delay between the firing of the initiators 33 and 34. The initiators 33 and 34 thus are fired sufficiently simultaneously that detonation fronts are generated at each end of the charge 22 and meet to produce a radially outward force which shears through the surrounding drill wall.

The end plate 32 and further plate 38 on the right hand side of the assembly, as shown, are movable. When setting up the assembly, the discs 23 are placed in position and the two plates 32 and 38 moved towards them, the plate 32 being arranged to securely abut charge 22 and the plate 38 being positioned to allow sufficient slack in the stripline 35 to place the end plate 32 in the required position, as illustrated in Figure 3a. The end plate 32 is clamped in position and then the second plate 38 is moved away from it, as shown by the arrow in Figure 3b. This enables different size explosive charges to be used without needing to alter the length of the stripline 35 or disturb the attachment of the EFI's 33 and 34 to it.

Figure 4 schematically illustrates a collar cutting assembly showing the location of the arrangement illustrated in Figure 2. The assembly includes centralising parts 39 and 40 to guide the assembly as it is dropped into position.

Another embodiment of the invention is schematically illustrated in Figure 5 and is similar to that shown in Figure 2. In this embodiment of the invention, a transformer 41 is included for providing an HT supply to the capacitor and is connected to a low voltage supply via lead 42. Also, each of the EFI's 43 and 44 is located adjacent a booster pellet 45 and 46 with a thin aluminium plate 47 and 48 between them. This enables the initiating mechanical shock produced by the EFI to be amplified prior to it being applied to the main explosive charge.

It should be noted that the dimensions of the arrangements shown in Figure 2 and 5 are not to scale. For example, the gaps between the charge and the end plates are exaggerated to enable the initiators and initiators/booster pellets to be more clearly shown.

In the arrangements shown in Figure 2 and 5 the transmission line to the lower EFI is arranged around the outer edge of the end plate. However, the end plate could be apertured and the stripline located through the aperture.

The EFIs and striplines are shown as being mounted on the surfaces of the end plates but they need not be fixed in position. In another embodiment, not shown, recesses are provided in each end plate 2 and the associated EFI (or booster pellet where one is used) is located in them to give a flush surface in contact with the explosive charge.

The initiators are shown adjacent the end faces of the elongate charge. However, they could be located on the outer, cylindrical surface but this arrangement is likely to be less efficient in generating the required transverse force.

## Claims

1. An explosive arrangement comprising: substantially elongate explosive charge means (22) having a longitudinal axis; and initiator means comprising at least two initiators (33, 34) disposed substantially adjacent the charge means (22) and spaced apart from one another in a longitudinal direction, the initiators (33, 34) being electrically initiated to detonate explosive material, the initiator means being arranged such that, when the initiators (33, 34) are initiated, detonation fronts are produced in the charge means (22) sufficiently simultaneously so as to meet and thereby produce a force in a direction transverse to the longitudinal axis.

2. An arrangement as claimed in claim 1 wherein the initiators are of the exploding foil initiator type (33, 34).

3. An arrangement as claimed in claim 1 or 2 wherein the initiators (33, 34) are arranged electrically in series.

4. An arrangement as claimed in claim 1, 2 or 3 wherein at least one of the initiators (33, 34) is connected to stripline (35) along which an electrical initiating signal is transmitted.

5. An arrangement as claimed in any preceding claim wherein at least one of the initiators (33, 34) is arranged to be directly in contact with explosive of the charge means (22).

6. An arrangement as claimed in claim 1, 2, 3 or 4 wherein at least one of the initiators (43, 44) initiates explosive of the charge means via a booster pellet (45, 46).

7. An arrangement as claimed in any preceding claim wherein at least one of the initiators (43, 44) includes a plate member (47, 48) which, upon initiation, transmits mechanical shock produced by the initiator to explosive material.

8. An arrangement as claimed in any preceding claim wherein an electrical initiating signal to one or both initiators is transmitted via a spark gap device (30).

**9.** An arrangement as claimed in claim 8 wherein one terminal of the spark gap device (30) is directly adjacent transmission line means (35) for transmitting the signal to the initiator or initiators (33, 34)

**10.** An arrangement as claimed in claim 8 or 9 wherein one terminal (29) of the spark gap device (30) is in direct contact with a terminal (27) of a capacitor (25) from which the electrical initiating signal is derived.

**11.** An arrangement as claimed in any preceding claim and including low inductance cylindrical capacitor means (25).

**12.** An arrangement as claimed in any preceding claim and including a housing (21) in which the explosive charge means (22) and initiators are contained.

**13.** An arrangement as claimed in claim 12 when dependent on claim 11 wherein the capacitor means (25) is included within the housing (21).

**14.** An arrangement as claimed in claim 13 and including transformer means (41) within the housing to provide a high voltage supply for the capacitor.

**15.** An arrangement as claimed in any preceding claim wherein the initiators (33, 34) are arranged adjacent to transverse end faces of the explosive charge means (22).

**16.** An arrangement as claimed in any preceding claim and including an end plate (32) adjacent one end of the explosive charge means (22), the end plate (32) being movable in a longitudinal direction.

**17.** An arrangement as claimed in claim 16 and including a second movable plate (38) located on the side of the end plate (32) other than that adjacent to the charge means (22), one of the initiators (34) being mounted on the end plate (32) and being connected by an electrical transmission line (35) to signal supply means (25, 30), the transmission line being located through an aperture in the second plate.

**18.** An arrangement as claimed in any preceding claim and including signal supply means (25, 30) for producing an electrical pulse to initiate the initiator or initiators (33, 34) having a peak current amplitude in the range 4 to 10kA with a pulse rise time in the range 20 to 100 nanoseconds.

**19.** An arrangement as claimed in any preceding claim and adapted for deployment in drill holes.

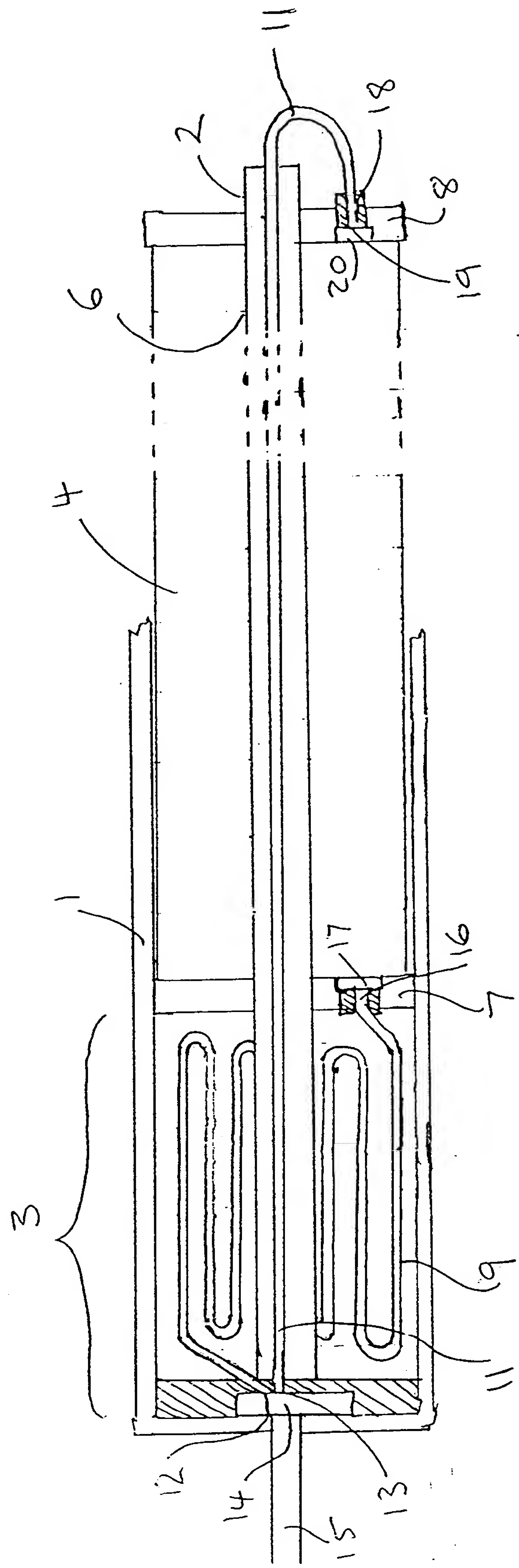
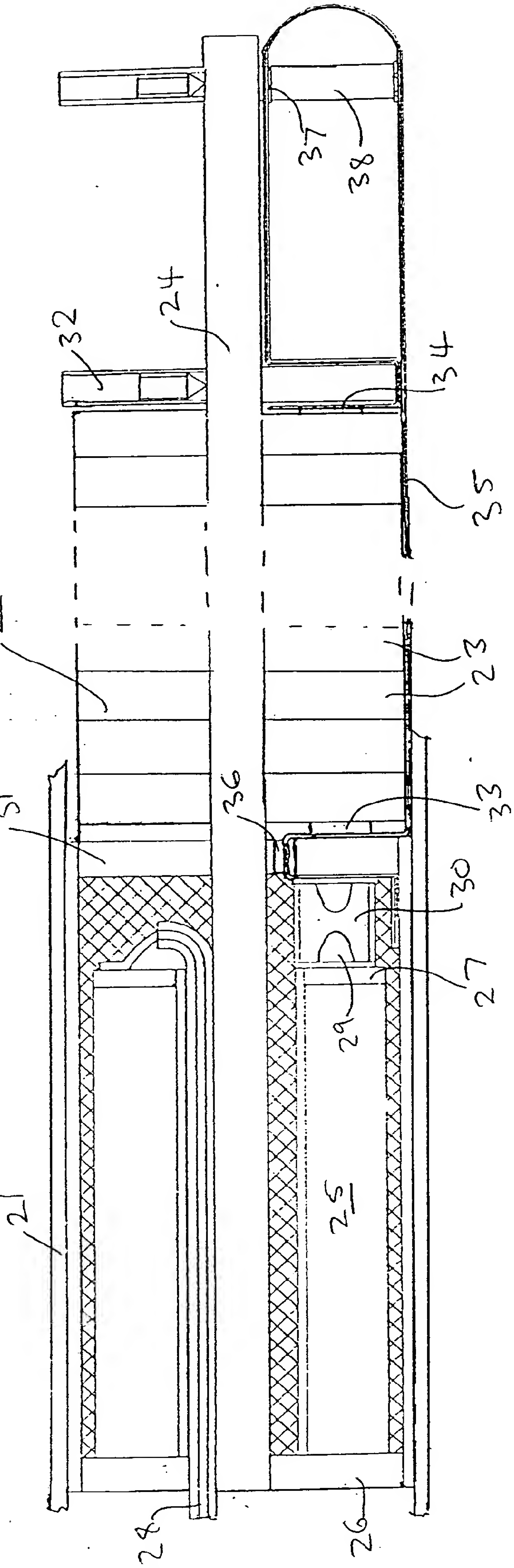



Fig. 1

PRIOR ART

Fig. 2



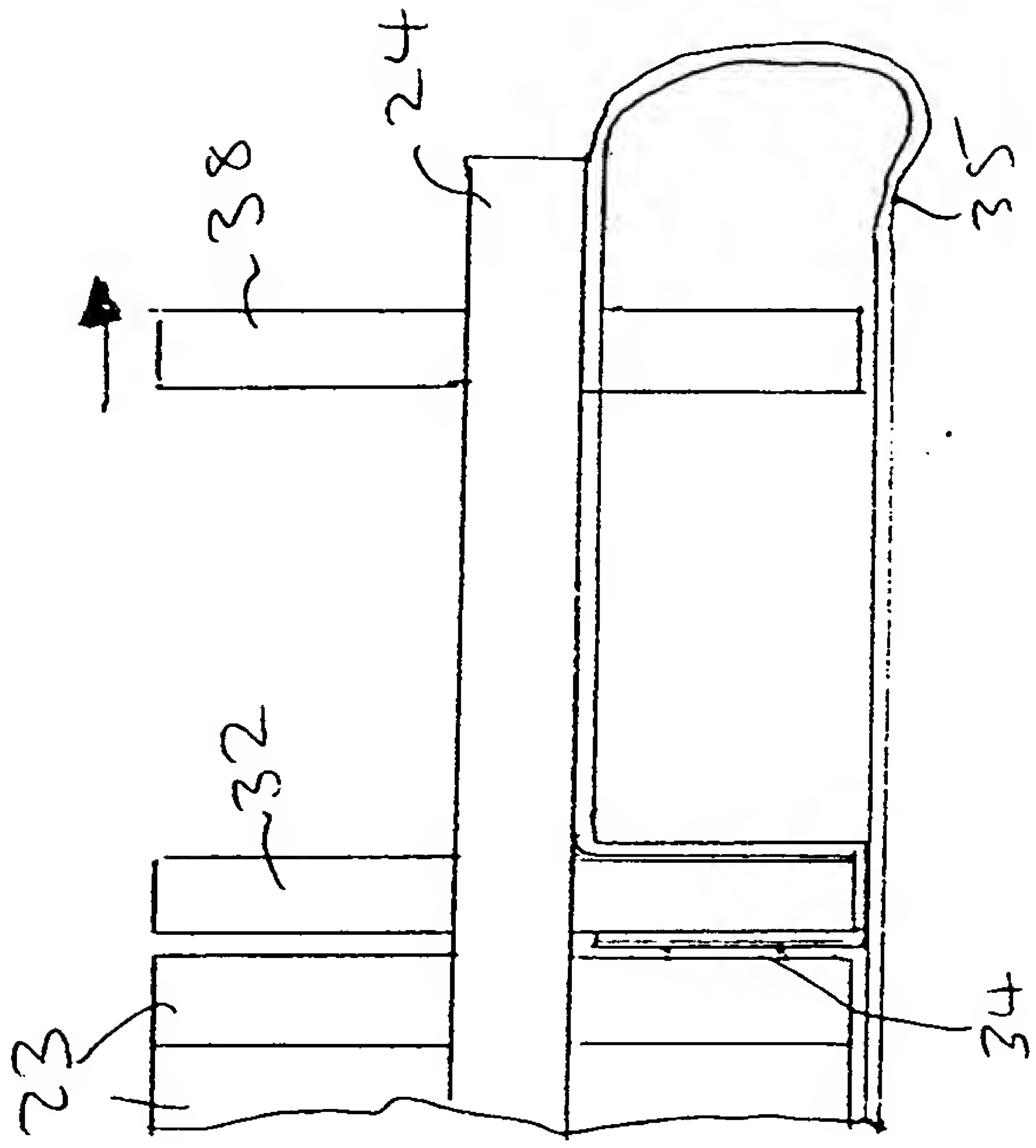



Fig 3b

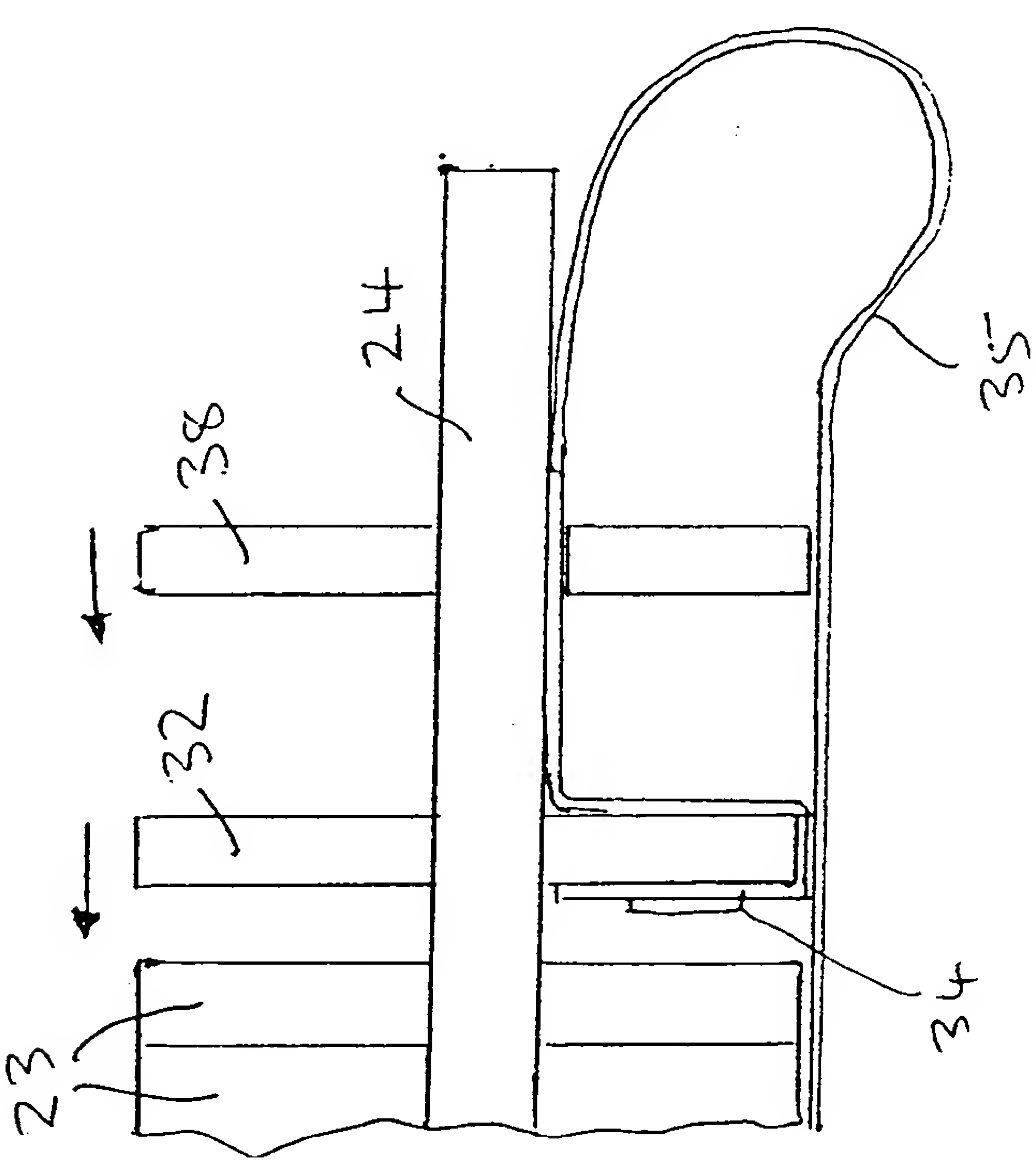



Fig 3a

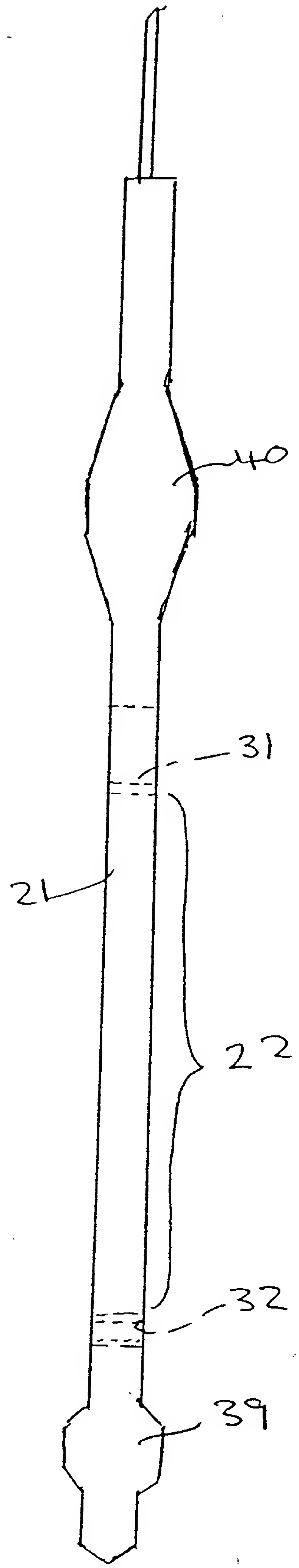
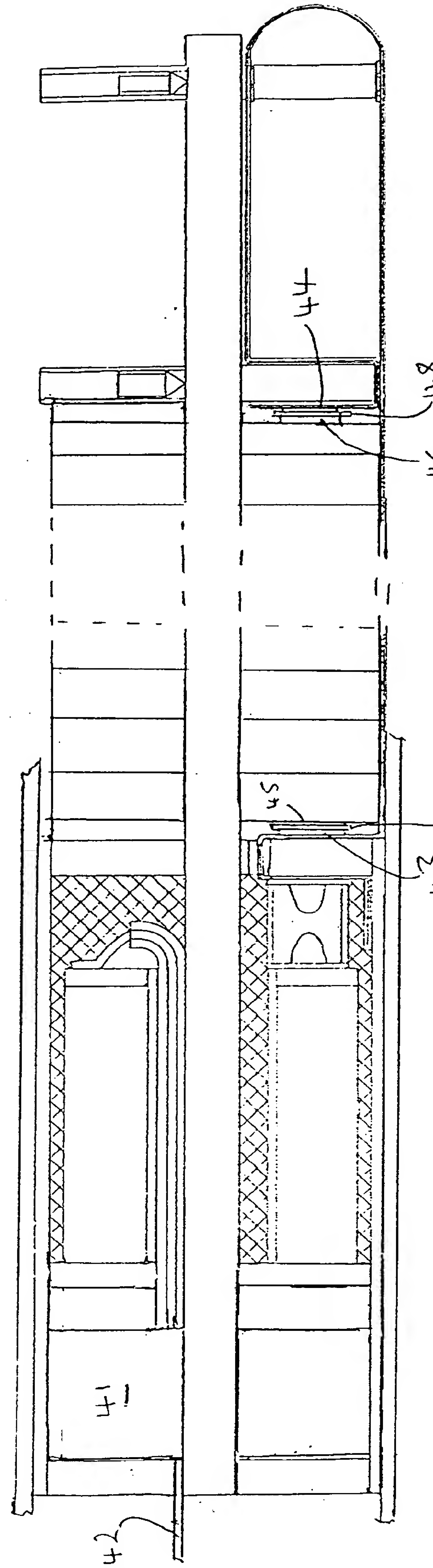



Fig. 4

Fig. 5



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# EUROPEAN SEARCH REPORT

Application Number

EP 93 30 1045

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5 ) |
|---|---|---|---|
| X<br>Y | US-A-4 493 260 (J.S.FOSTER)<br>* the whole document * | 1,15<br>2,3,7,8,<br>11,14 | F42D3/00<br>F42D1/04 |
| Y | US-A-4 944 225 (J.M.BARKER)<br>* column 3, line 9 - column 6, line 28; figures 1-4 * | 2 | |
| Y<br>A | US-A-3 726 215 (D.A.COLPITTS)<br>* column 1, line 41 - column 2, line 9; figures * | 3<br>1 | |
| Y | EP-A-0 040 011 (EMI LIMITED)<br>* page 3, line 5 - line 29 * | 7 | |
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| A | US-A-4 008 117 (G.L.DYBWAD) | 2,10,14 | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 28 APRIL 1993 | P. TRIANTAPHILLOU |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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